Selective-TCP for Wired/Wireless Networks

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Roadmap

- Motivation
- Background
- Related work
- Selective-TCP algorithm
- Simulation results
- Conclusion and future work

Motivation

- TCP is a transport protocol extensively used over the Internet: 95% of IP traffic in 2002
- TCP performance degrades over wireless network and thus also over mixed wired-wireless network, which are integral part of today's communication technology (cellular network)
- Main reason for TCP's poor performance over wireless networks is TCP's inability to distinguish losses in wireless links from congestion

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Background

- Three approaches:
  - end-to-end: TCP-Reno, NewReno
  - split connection: I-TCP, M-TCP
  - link layer level: Snoop, packet-control
- End-to-end schemes are promising:
  - significant performance gain without help from intermediate nodes: though not as effective as LL-level approaches in handling wireless losses

H. Balakrishnan, V. N. Padmanabhan, S. Seshan, and R. H. Katz, "A comparison of mechanisms for improving TCP performance over wireless links," *Computer Communication Review,* 1996.

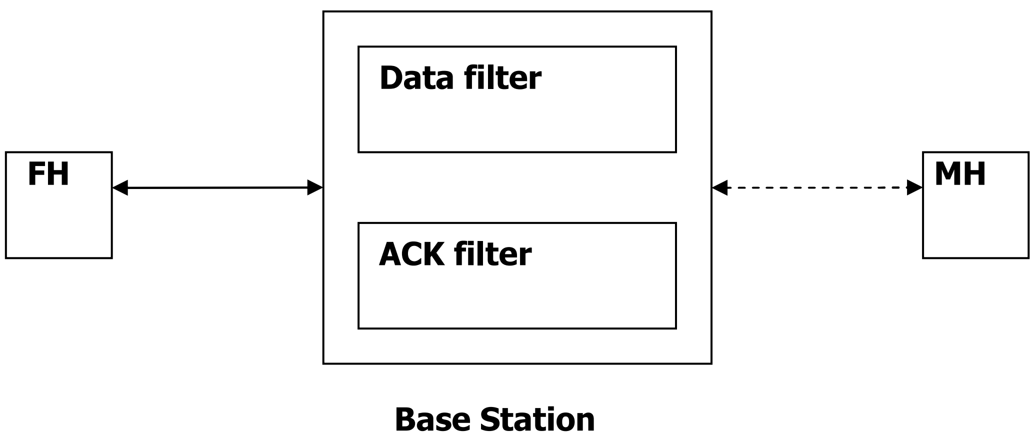
Packet control algorithm: overview

- A link-layer level based approach to improve TCP performance over wired-wireless network:
  - modifications made in the intermediate node (base station): implemented in NS version 2.26
  - addresses two problems specific to wireless networks
    - delay variation (spurious fast retransmit)
    - sudden large delays (spurious fast timeout)
  - hides wireless losses from TCP sender (fixed host)
  - filtering done locally at base station

W. G. Zeng and Lj. Trajkovic, "TCP packet control for wireless networks," *IEEE Int. Conf. on Wireless and Mobile Computing, Networking and Communications (WiMob 2005)*, Montreal, Canada, Aug. 2005, pp. 196–203.

Packet control algorithm: filters

- Improves TCP performance by avoiding the adverse effects of:
  - delay variations (spurious fast retransmit)
  - sudden large delays (spurious fast timeout) of wireless links
- Introduces two filters at the base station:
  - Data filter
  - ACK filter



Packet control algorithm: data filter

- Data filter: filters data segments, sent from fixed host

```
if (new or unacknowledged data segment)
        forward to receiver (mobile host)
else // acknowledged data segment
        drop the segment
```

Packet control algorithm: ACK filter

- ACK filter: filters ACKs, sent from mobile host

```
if (old ACK received)
   drop the ACK
else if  (new ACK received) {
   i) update last_received_ACK
   ii) reset number of DUP_ACKs to 0
   iii) forward the ACK to fixed host
   }
else   //duplicate ACK received {
   i) update number of DUP_ACKs
   ii) drop or forward the duplicate ACKs depending
   on user-defined DUPACK_threshold
   }
```

Packet control algorithm: summary

- Reduces the adverse effect of spurious fast retransmit and timeout
- TCP goodput is improved by 30% in wireless networks with 1% packet loss, compared to the performance of TCP-Reno

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Related work

- Improving TCP performance over wired-wireless network by detecting the type of loss:
- End-to-end:

C. P. Fu and S. C. Liew, "TCP Veno: TCP enhancement for transmission over wireless access networks," *IEEE J. on Select. Areas Commun.,* vol. 21, no. 2, pp. 216–228, Feb. 2003.

N. K. G. Samaraweera, "Non-congestion packet loss detection for TCP error recovery using wireless links," *IEE Proc. Communications,* vol. 146, no. 4, pp. 222–230, Aug. 1999.

D. Barman and I. Matta, "Effectiveness of loss labeling in improving TCP performance in wired/wireless networks," in *Proc. 10th IEEE Int. Conf. on Network Protocols*, Boston, MA, Nov. 2002, pp. 2–11.

C. Parsa and J. J. Garcia-Luna-Aceves, "Differentiating congestion vs. random loss: a method for improving TCP performance over wireless links," in *Proc. IEEE Conf. on Wireless Communications and Networking*, Chicago, IL, Sept. 2000, vol. 1, pp. 90–93.

T. Kim, S. Lu, and V. Bharghavan, "Improving congestion control performance through loss differentiation," in *Proc. Eighth International Conference on Computer Communications and Networks*, Boston, MA, Oct. 1999, pp. 412–418.

Related work

- Improving TCP performance over wired-wireless network by detecting the type of loss:
- Link layer level:

F. Sun, V. O. K. Li, and S. C. Liew, "Design of SNACK mechanism for wireless TCP with new snoop," in *Proc. IEEE Wireless Communications and Networking Conference*, Atlanta, GA, Mar. 2004, vol. 2, pp. 1051–1056.

K. Xu, Y. Tian, and N. Ansari, "TCP-Jersey for wireless IP communications," *IEEE J. Select. Areas Commun.,* vol. 22, no. 4, pp. 747–756, May 2004.

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Selective-TCP algorithm: overview

- An end-to-end solution
- Implemented in ns-2 version 2.27
- Type of loss detected at the receiver (using Biaz-scheme)
- Corrective measures:
  - wireless loss: Selective Negative Acknowledgement (Snack) sent to the sender
  - congestion loss: sender's congestion window size set according to the bandwidth measured at the receiver

S. Biaz and N.H. Vaidya, "Discriminating congestion losses from wireless losses using inter-arrival times at the receiver," in *Proc. ASSET*, 24-27 March 1999, pp. 10-17.

D. Anantharaman, "Performance analysis of snack in satellite networks through simulation," M.S. Thesis, Lamar University, Lamar, TX, 2004.

Biaz-scheme

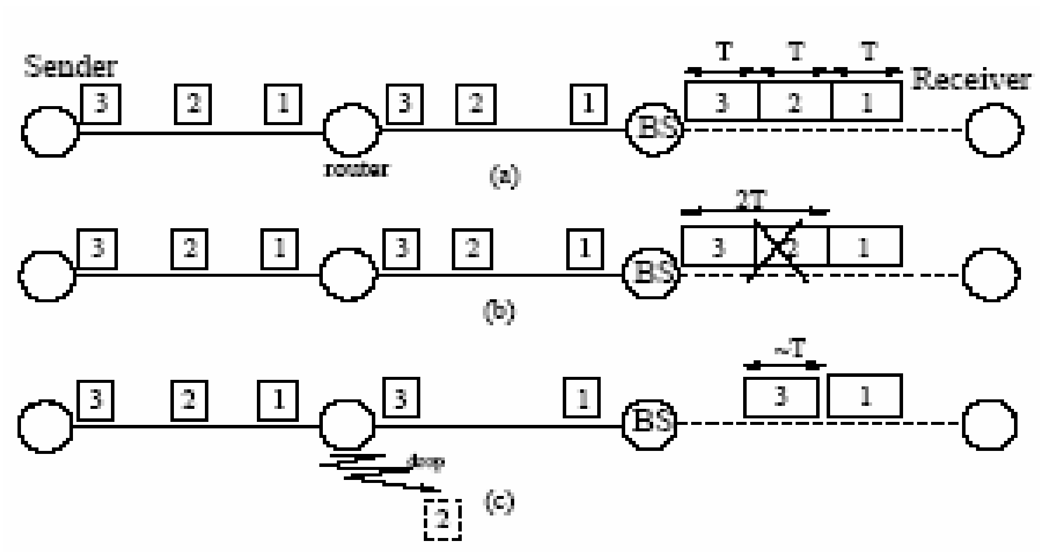
- Detects the type of loss based on the packet inter-arrival times at the receiver
- Assumes the following:
  - wireless link is the bottleneck
  - sender performs bulk data transfer
  - on the connection path, only the last link is wireless
- Given the assumptions, accuracy of detection is high

S. Biaz and N.H. Vaidya, "Discriminating congestion losses from wireless losses using inter-arrival times at the receiver," in *Proc. ASSET'99*, 24-27 March 1999, pp. 10-17.

S. Cen, P.C. Cosman, and G.M. Voelker, "End-to-end differentiation of congestion and wireless losses," *Proc. of the SPIE - the International Society for Optical Engineering,* vol. 4673, pp. 1-15. 2001

Biaz-scheme

- Wireless link is the bottleneck: packets will queue at the base station



- Thus for a single packet loss:

  If (T < time_gap < 2T) { wireless loss }

  Else { congestion loss }

TCP-Snack

- An option of satellite communication protocol stack-transport protocol (SCPS-TP)
- Widely used for satellite links
- Negative: receiver informs sender about the segments not received
- Selective: can send information for more than one lost segments:
  - good for long delay networks
- When a sender receives Snack:
  - aggressively retransmits packets indicated as holes, preventing unnecessary retransmission time-outs

Consultative Committee for Space Data Systems, *Space Communications Protocol Specification—Transport Protocol (SCPS-TP)*, Blue Book, issue 1, May 1999.

Selective-TCP algorithm: module at receiver

```
If (out of order packet received) {
        // check type of loss using Biaz-sheme
        if ( wireless loss){
                if (snack_delay=0)
                        send Snack
                else
                        do nothing
                }
        else // congestion loss {
                set congestion_count= congestion_count+1
                set BW= current bandwith measured at receiver
                if (congestion_count=k) {
                        send BW to TCP sender as "congestion_info" header option
                        reset  congestion_count
                        }
                else
                        send ACK //like standard TCP sink
                }
        }
 Else // in-sequence packet received
        send ACK (same as standard TCP-sink)
```

Selective-TCP: module at TCP sender

```
If (Snack received) {
        retransmit lost packet(s) indicated as hole(s)
        reset retransmission timer
        }
Else if (congestion_info received) {
         //set congestion_window as BW measured at receiver
        set congestion_window_size=congestion_info
        reset congestion_info
        }
Else //normal ACK received
        do as TCP-newreno sender
```

Selective-TCP algorithm: description

- In case of wireless loss, the receiver sends Snack
  - sender retransmits the lost packets immediately without waiting for retransmission timer to expire:
    - no duplicate ACKs sent
    - congestion control not invoked
  - Snack is selective
    - helps in presence of packet-reordering in long-delay networks
  - result: increased link bandwidth utilization and better goodput

Selective-TCP algorithm: description

- In case of congestion loss:
  - sender’s congestion window size is set as the bandwidth measured at receiver
  - TCP’s AIMD algorithm is prevented from setting congestion window much too lower than necessary
  - result: increased bandwidth utilization and better goodput

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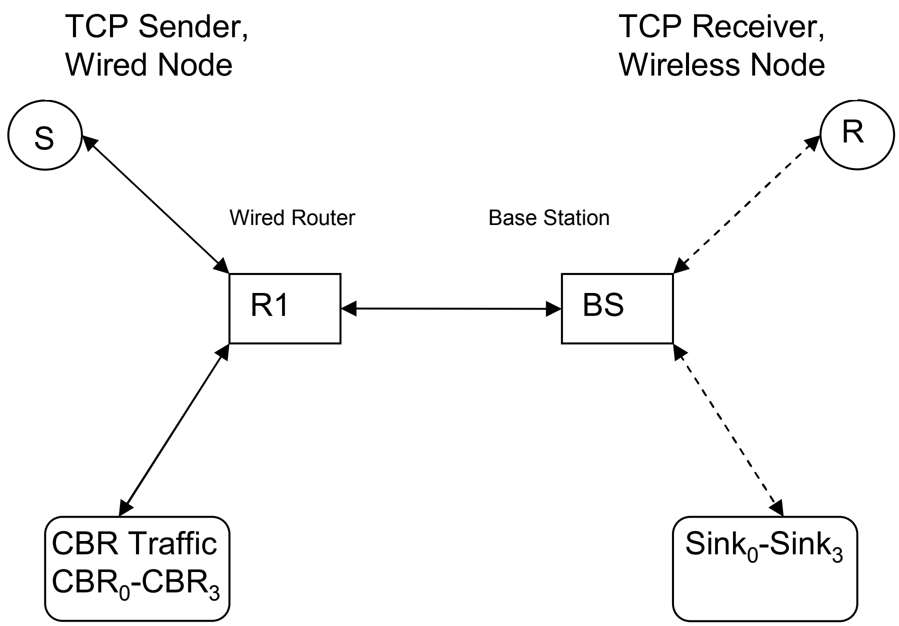
Simulation scenario: network topology

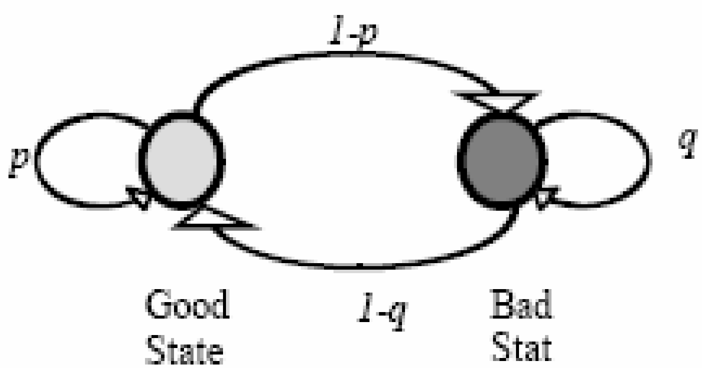


- Wired link: bandwidth 2–3 Mb, propagation delay 5 ms
- Wireless link: bandwidth 1 Mb, propagation delay 1 ms

Simulation scenario: error model

- Two-state Markov model for modeling burst errors over wireless link

$$\Pi_j = \begin{pmatrix} p & 1-p \\ 1-q & q \end{pmatrix} \qquad \varepsilon = \frac{1-p}{2-p-q} \qquad (1)$$



Simulations:

good state: 0 packet loss

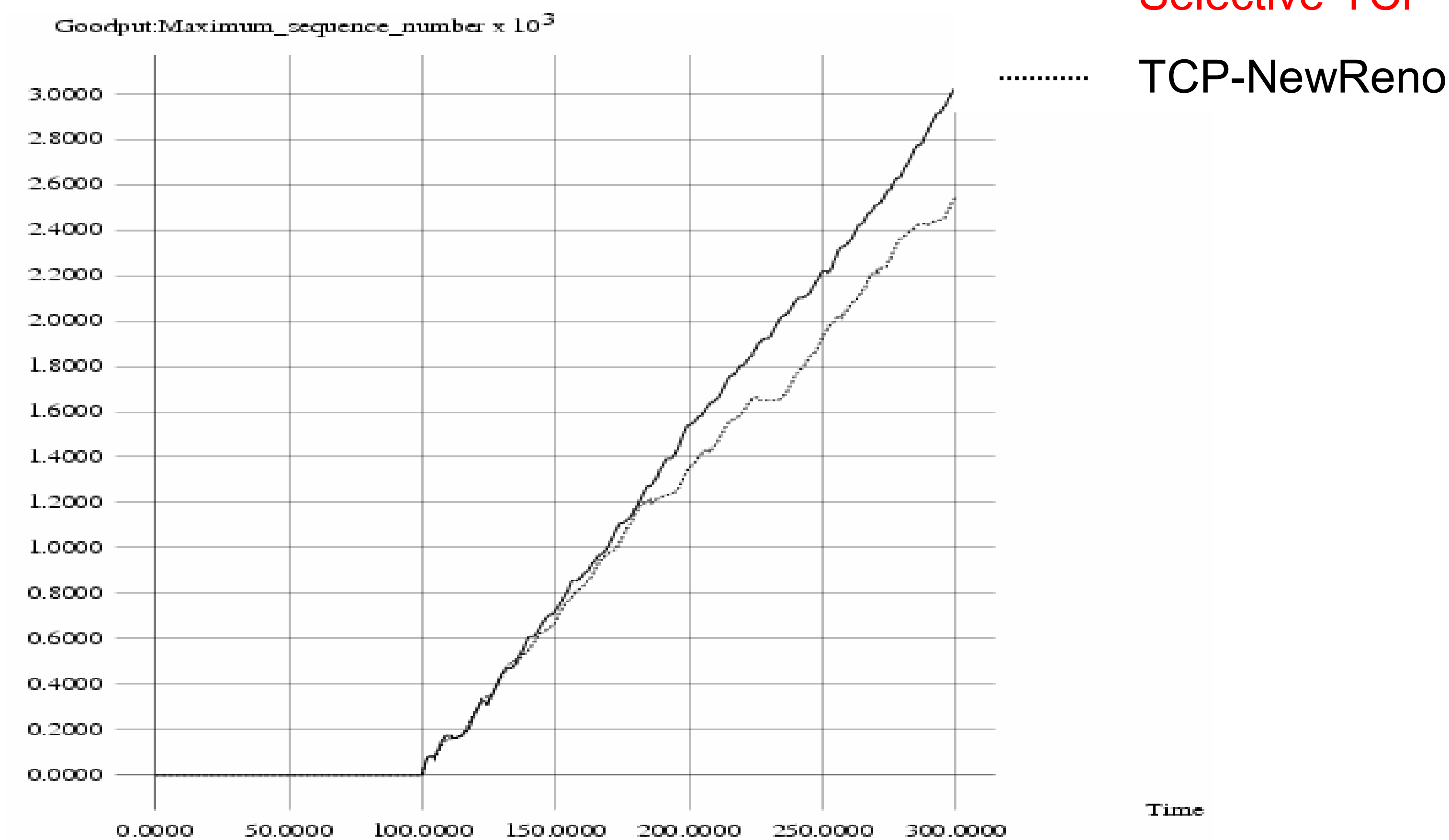
bad state: 1 packet loss

A. Gurtov and S. Floyd, "Modeling wireless links for transport protocols," *Computer Communication Review,* vol. 34, pp. 85-96, 2004.

J. McDougall and S. Miller, "Sensitivity of wireless network simulations to a two-state Markov model channel approximation," in GLOBECOM '03. *IEEE Global Telecommunications Conference*, 1-5 Dec. , 2003, pp. 697-701

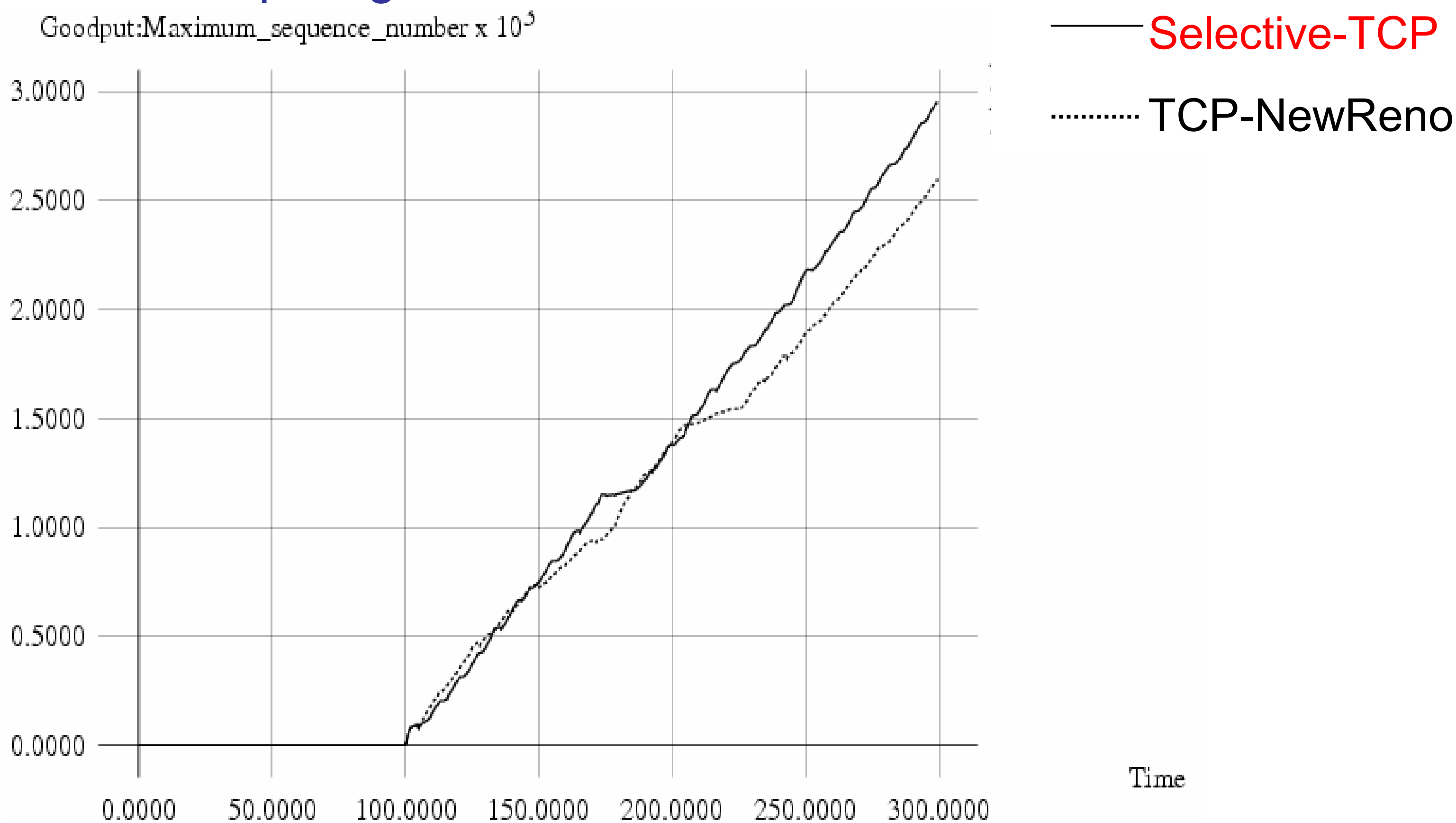
Simulation results: goodput vs. time

With competing traffic:



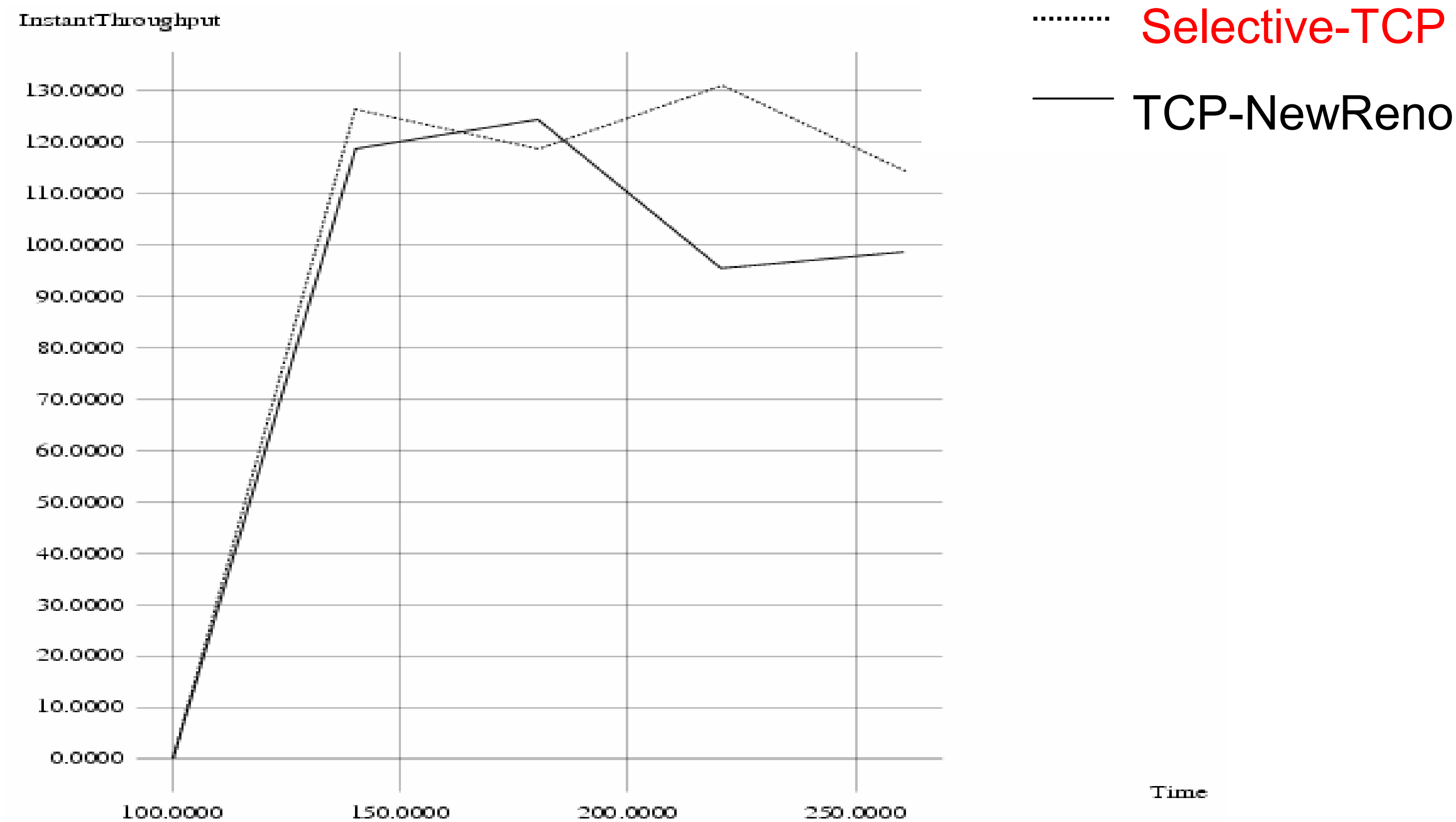
Simulation results: goodput vs. time

Without competing traffic:



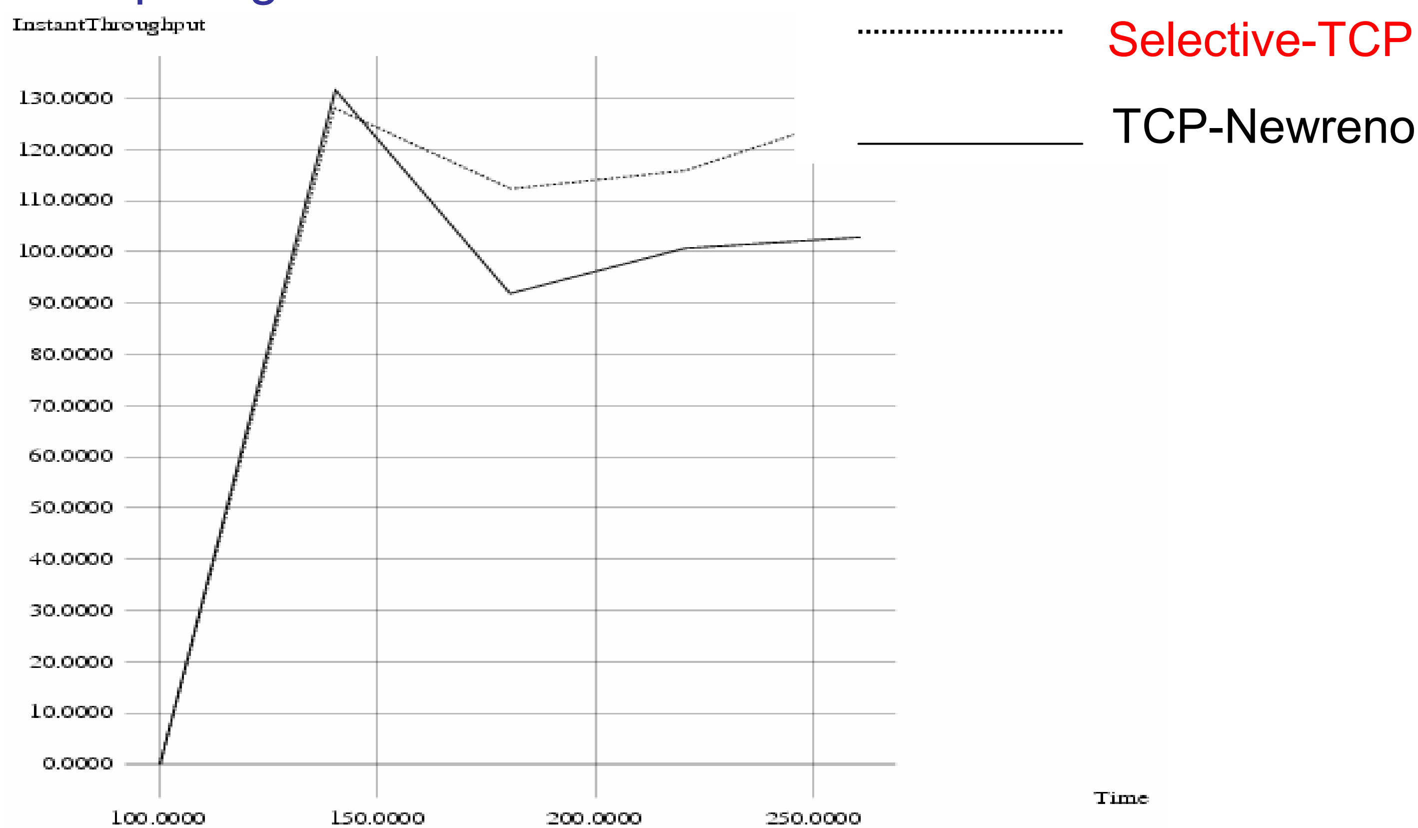
Simulation results: instant throughput vs. time

With competing traffic:



Simulation Results: instant throughput vs. time

Without competing traffic



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Conclusion and future work

- Selective-TCP improves Goodput up to 20% over wired-wireless network
- Future work:
  - studying performance variations with varying error rates
  - delaying duplicate ACKs at the receiver
  - comparing with packet control algorithm

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